CONSTRUCTION-EQUIPMENT
BRAKE SYSTEMS

Subcourse EN5258

EDITION A

United States Army Engineer School
Fort Leonard Wood, Missouri 65473

7 Credit Hours

Edition Date: March 1999

SUBCOURSE OVERVIEW

This subcourse is part of the military occupational specialty (MOS) 62B Construction Equipment Repairer Course. It is designed to teach the knowledge and skills necessary to perform tasks related to servicing and maintaining brake systems found on items of engineer equipment. This subcourse is presented in five lessons, each corresponding to a terminal learning objective as indicated below.

There are no prerequisites for this subcourse.

This subcourse reflects the doctrine which was current at the time it was prepared. In your own work situation, always refer to the latest official publications.

Unless otherwise stated, the masculine gender of singular pronouns is used to refer to both men and women.

Appendix A contains a metric conversion chart.

TERMINAL LEARNING OBJECTIVE:

ACTION: You will learn the basic principles of automotive brake systems, including their construction and operation, and how to troubleshoot the system.

CONDITION: You will be given the material in this subcourse, paper, a number (No.) 2 pencil, and an Army Correspondence Course Program (ACCP) examination response sheet.

STANDARD: To demonstrate competency of this task, you must achieve a minimum of 70 percent on this subcourse.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subcourse Overview</td>
<td>i</td>
</tr>
<tr>
<td>Lesson 1: Brake-System Principles</td>
<td>1-1</td>
</tr>
<tr>
<td>Practice Exercise</td>
<td>1-15</td>
</tr>
<tr>
<td>Answer Key and Feedback</td>
<td>1-18</td>
</tr>
<tr>
<td>Lesson 2: Hydraulic Brake Systems</td>
<td>2-1</td>
</tr>
<tr>
<td>Part A - Principles</td>
<td>2-1</td>
</tr>
<tr>
<td>Part B - Troubleshooting</td>
<td>2-9</td>
</tr>
<tr>
<td>Practice Exercise</td>
<td>2-17</td>
</tr>
<tr>
<td>Answer Key and Feedback</td>
<td>2-20</td>
</tr>
<tr>
<td>Lesson 3: Compressed-Air Brake Systems</td>
<td>3-1</td>
</tr>
<tr>
<td>Part A - Principles and Basic Components</td>
<td>3-1</td>
</tr>
<tr>
<td>Part B - Troubleshooting</td>
<td>3-11</td>
</tr>
<tr>
<td>Practice Exercise</td>
<td>3-19</td>
</tr>
<tr>
<td>Answer Key and Feedback</td>
<td>3-22</td>
</tr>
<tr>
<td>Lesson 4: Air-Over-Hydraulic Brake Systems</td>
<td>4-1</td>
</tr>
<tr>
<td>Part A - Construction and Operation</td>
<td>4-2</td>
</tr>
<tr>
<td>Part B - Troubleshooting</td>
<td>4-5</td>
</tr>
<tr>
<td>Practice Exercise</td>
<td>4-9</td>
</tr>
<tr>
<td>Answer Key and Feedback</td>
<td>4-12</td>
</tr>
<tr>
<td>Section</td>
<td>Page</td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>Lesson 5: D7G Brake System</td>
<td>5-1</td>
</tr>
<tr>
<td>Part A - Operation</td>
<td>5-1</td>
</tr>
<tr>
<td>Part B Troubleshooting</td>
<td>5-2</td>
</tr>
<tr>
<td>Practice Exercise</td>
<td>5-7</td>
</tr>
<tr>
<td>Answer Key and Feedback</td>
<td>5-10</td>
</tr>
<tr>
<td>Appendix A: Metric Conversion Chart</td>
<td>A-1</td>
</tr>
<tr>
<td>Appendix B: List of Common Acronyms</td>
<td>B-1</td>
</tr>
<tr>
<td>Appendix C: Recommended Reading List</td>
<td>C-1</td>
</tr>
<tr>
<td>Appendix D: Publication Extracts</td>
<td>D-1</td>
</tr>
</tbody>
</table>

**TM 5-2420-224-20-1**


**TM 5-2420-224-20-2**


**TM 5-3805-262-20**

*Organizational Maintenance, Loader, Scoop Type, DED 4x4, Articulated Frame Steer, 2 1/2 Cubic Yard, (J.I. Case Model MW24C)(NSN 3805-01-150-4814). 1 September 1987.*

**TM 5-3805-262-24P**


**TM 5-3810-293-14&P-1**

*Operator's, Organizational, Direct Support, General Support, and Depot Maintenance Manual Including*
Use the above publication extracts to take this subcourse. At the time we wrote this subcourse, these were the current publications. In your own work situation, always refer to the latest publications.
LESSON 1
BRAKE-SYSTEM PRINCIPLES

Critical Tasks: 091-62B-1005
091-62B-3054

OVERVIEW

LESSON DESCRIPTION:
In this lesson, you will learn about the principles of brake systems and how to identify the major components that make up most brake systems in use today.

TERMINAL LEARNING OBJECTIVE:

ACTION: You will learn the principles of automotive brake systems, including the construction and operation of mechanical, air, and hydraulic brake systems.

CONDITION: You will be given the material contained in this lesson.

STANDARD: You will correctly answer practice exercise questions at the end of this lesson.

REFERENCE: The material contained in this lesson was derived from the TM 9-8000.

INTRODUCTION

Braking action is the use of a controlled force to slow down or stop an object or to hold that object in a stationary position. Braking action is the result of friction caused by two surfaces rubbing together. An example of friction is the force that tries to stop your hand as you apply pressure and slide it across a table or a desk. This means that by forcing the surface of an object that is not moving (stationary) against a moving object's surface, the resistance to movement or the rubbing action between the two surfaces of the objects will slow down the moving surface. In a braking system, one surface is rotating and one surface is nonrotating.

1-1. Brake History. Brakes on early motor vehicles were nothing more than modified wagon brakes used on horse-drawn wagons. These were hand-operated, mechanical, lever-type brakes that forced a piece of wood against one or more wheels, causing friction or a drag on the wheel or wheels as shown in Figure 1-1, page 1-2. This action also results in friction between the wheel and the ground that tries to prevent the wheel from sliding or skidding.
1-2. **External-Contracting and Internal-Expanding Brakes.** There are many different types of brake systems. All systems require the use of a rotating and nonrotating unit. Each of these units has braking surfaces, which when forced together, produce the friction required for braking action. The rotating unit on many military vehicle brakes consists of a drum that is secured to and driven by a wheel. The nonrotating unit consists brake shoes and the linkage required to apply the brake shoes to the drum. Brakes may be external-contracting or internal-expanding (Figures 1-2 and 1-3), depending on how the stationary surface is forced against the rotating surface.
1-3. **Rotating and Nonrotating Brake-Drum Units.** The brake drum is mounted directly on the wheel that provides the rotating surface, and the brake shoe is mounted on the nonrotating surface. The primary function of the brake-drum assembly is to force the brake shoe against the rotating drum to provide the braking action.

a. Self-energizing action. Most brake drum assemblies use what is called *self-energizing action*. This self-energizing action is produced as the brake shoe engages the rotating brake drum. As the brake-actuating mechanism forces the brake shoes outward, as shown in A, Figure 1-4, page 1-4, the top of the brake shoe tends to stick or wedge to the rotating brake drum and rotates with it. This effect on the brake shoe greatly reduces the amount of effort required to achieve a given amount of retardation. If two brake shoes were linked together, as shown in B, Figure 1-4, application of the brakes would produce self-energizing and servo effects. The servo effect is a result of the primary shoe or the brake shoe that is facing towards the front of the vehicle attempting to rotate with the brake drum. Due to both shoes being linked together, the rotating force of the primary shoe applies the secondary shoe. In the forward position, the anchor point for both brake shoes is at the heel of the secondary brake shoe. As the vehicle changes direction, the toe of the primary brake shoe becomes the anchor point, and the direction of self-energizing and servo actions change as shown in C, Figure 1-4.
Figure 1-4. Self-energizing and servo actions
b. Brake-drum assembly configurations. The most popular configurations of brake-drum assemblies are discussed below.

(1) Single-anchor, self-energizing servo action. In this configuration (A, Figure 1-5, page 1-6), both brake shoes are self-energizing in forward and reverse directions. The brake shoes are self-centering and provide servo action during brake application. This system has one anchor pin, which is rigidly mounted to the backing plate and is nonadjustable. Both forward and reverse brake torques are transmitted to the backing plate through the anchor pin. One brake cylinder with dual pistons is used in this configuration.

(2) Single-anchor, self-centering. In this configuration (B, Figure 1-5), only the primary brake shoe is self-energizing in the forward direction and therefore provides the majority of the brake force. This system is self-centering, in that the lower shoe anchor does not fix the position of the brake shoes in relation to the brake drum. The brake shoes are allowed to move up and down as needed. This system has one brake cylinder.

(3) Double-anchor, single cylinder. In this configuration (C, Figure 1-5), each brake shoe is anchored at the bottom by rotating eccentric-shaped anchor pins. Only the primary shoe is self-energizing, and the system does not develop servo action. Spring clips are used at the middle of the shoe to hold the shoes against the backing plate. This system has one wheel-brake cylinder.

(4) Double-anchor, double cylinder. In this configuration (D, Figure 1-5), the brake shoes are provided with an anchor at each heel. The anchors are eccentric-shaped to allow for adjustment and centering. Each shoe has a single-piston cylinder mounted at the toe of the brake shoes, which allows both brake shoes to be self-energizing in the forward direction only.

1-4. Brake-Drum Construction. Brake drums are made of pressed steel, cast iron, or a combination of two metals, or aluminum.

a. Cast-iron brake drums. These brake drums dissipate the heat generated by friction faster than steel drums and have a higher coefficient friction with any particular brake lining. However, cast-iron drums of sufficient strength are heavier than steel drums. To provide lightweight brake drums with sufficient strength, centrifuge brake drums (Figure 1-6, page 1-6) made of steel with a cast-iron liner for the braking surface are used. A solid cast-iron brake drum of the same total thickness as the centrifuge drum would be too weak, while one of sufficient strength would be too heavy for the average passenger car.
Figure 1-5. Brake-drum assembly configurations

Figure 1-6. Brake-drum construction
b. Aluminum brake drums. These brake drums are constructed similar to centrifuge drums. They consist of aluminum casting with a cast-iron liner for a braking surface.

While reducing weight, this design allows heat to be transferred to the surrounding atmosphere more readily. Cooling fins or ribs are also added to most brake drums to allow heat to be transferred to the atmosphere more readily, thereby keeping the brake drum cooler and helping minimize brake fade.

c. Brake-drum surfaces. For good braking action, the brake drum should be perfectly round and have a uniform surface. Brake drums become out of round from pressure exerted by brake shoes and from heat developed by the application of the brakes. The brake-drum surface becomes scored when it is worn by the braking action. When the surface is scored or the brake drum is out of round, it may be necessary to machine the brake drum until it is smooth and true again.

1-5. Brake-Shoe and Lining Construction. The brake shoes and lining (Figure 1-7) work together. The brake shoes are used to support, strengthen, and move the brake lining.

a. Brake shoe. The brake shoe is made of malleable iron, cast steel, drop-forged steel, pressed steel, or cast aluminum. Pressed steel is commonly used because it is cheaper to produce in large quantities. A steel brake shoe expands at about the same rate as the brake drum when heat is generated by brake application, thereby maintaining the clearance between the brake drum and brake shoe under most conditions.

Figure 1-7. Brake shoes and brake lining
b. Brake lining. The brake lining is riveted or bonded to the face of the brake shoe, and it makes contact with the inner surface of the brake drum. Brass rivets are chosen over other types, because brass does not score the brake drum excessively if the lining is worn past the point of replacement. Aluminum rivets are not used because they may corrode due to moisture. The brake lining may be bonded to the brake shoe with special cement. It is not always necessary to fasten the lining to the shoe. In some brake assemblies, the lining is not fastened to the brake shoe or the brake drum but floats between them and is held by a lining retainer on one side and the brake shield on the other side.

c. Brake-lining types. Variations in brake design and operation make it necessary to have different types of brake linings as shown in Figure 1-7, page 1-7. Brake linings come in molded and woven types.

(1) Molded. This lining is made of dense, compact asbestos fibers. The lining is sometimes impregnated with fine copper wire and may be cut into blocks to fit different sizes so that they will match the corresponding brake shoes. Its frictional qualities are low because it has a smooth surface, but it dissipates heat rapidly and wears longer than woven brake lining.

(2) Woven. This lining is made of asbestos or cotton fibers and copper or bronze wire. After being woven, the lining is treated with compounds intended to lessen the effects of water and oil. The lining is also compressed and heat-treated before being installed. The main advantage of the woven lining is its high-frictional qualities. Woven lining does not dissipate heat as rapidly as molded brake lining.

1-6. Disk-Brake System. This system consists of a disk-brake assembly, floating or fixed calipers, and multipiston designs.

a. Disk-brake operation. The disk-brake assembly (Figure 1-8), like the brake-drum assembly, is operated by pressurized hydraulic fluid. The fluid, which is routed to the calipers through steel lines and flexible high-pressure hoses, develops its pressure in the master cylinder. Once the brake pedal is depressed, fluid enters the caliper and begins to force the piston(s) outward. This outward movement forces the brake pads against the moving rotor. Once this point is reached, the braking action begins. The greater the fluid pressure exerted on the piston(s) from the master cylinder, the tighter the brake pads will be forced against the rotor. This increase in pressure will cause an increase in braking effect. As the pedal is released, pressure diminishes and the force on the brake pads is reduced. This allows the rotor to turn more easily. Some calipers allow the brake pads to rub lightly against the rotor at all times in the released position. Another design uses the rolling action on the piston seal to maintain a clearance of approximately 0.005 inch (Figure 1-8) when the brakes are released.
Figure 1-8. Disk-brake assembly
b. Disk-brake versus brake drum assemblies. Both the disk-brake and the brake-drum assemblies are used on modern vehicles and are well-designed systems. Each system exhibits certain inherent advantages and disadvantages. The most important point of interest are discussed below. One major factor that must be discussed in automotive brakes, as well as all other brake systems, is the system's ability to dissipate heat. As discussed previously, the by-product of friction is heat. Because most brake systems use this concept to develop braking force, it is highly desirable for brake systems to dissipate heat as rapidly and efficiently as possible. The disk-brake assembly, because of its open design, has the ability to dissipate heat faster than the brake-drum assembly. This feature makes the disk-brake assembly less prone to brake fade due to a buildup of excess heat. The disk-brake assembly may have additional heat-transfer qualities due to the use of a ventilated rotor. This type of rotor (Figure 1-8, page 1-9) has built-in air passages between friction surfaces to aid in cooling.

(1) While the brake-drum assembly requires an initial shoe to-drum clearance adjustment and periodic checks, the disk-brake assembly is self-adjusting and maintains proper adjustment at all times. The disk-brake assembly automatically compensates for lining wear by allowing the piston in the caliper to move outward, thereby taking up excess clearance between the pads and the rotor. The disk system is simple in comparison to the drum system. Due to its design and lack of moving parts and springs, the disk-brake assembly is less likely to malfunction than the brake-drum assembly.

(2) Overhauling the disk-brake assembly is faster because of its simple design. It is also safer due to the fact that the disk-brake assembly is open and asbestos dust from the linings is less apt to be caught in the brake assembly. Like brake drums, rotors may be machined if excessive scoring is present. Rotors are also stamped with a minimum thickness dimension, which should not be exceeded. The brake-drum assembly requires the drum to be removed for lining inspection. Some disk pads have a built-in lining wear indicator that produces an audible high-pitch squeal when the linings are worn excessively. This harsh squeal is a result of the lining wearing to a point that allows a metal indicator to rub against the rotor as the wheel turns. Because of its small frictional area, and lack of self-energizing and servo effect, the disk-brake assembly requires the use of an auxiliary power booster to develop enough hydraulic pressure for good braking.

c. Floating calipers. Floating calipers (Figure 1-9) are designed to move laterally on their mounts. This movement allows a caliper to maintain a centered position with respect to the rotor. This design also permits the braking force to be applied equally to both sides of the rotor. A floating caliper usually is of one-piece, solid construction and uses a single piston to develop the braking force. This type of caliper operates by pressurized hydraulic fluid like all other hydraulic calipers. The fluid enters the piston cavity and begins to force the piston outward. As this happens, the brake pad meets the rotor. Additional pressure then forces the caliper assembly to move in the opposite direction of the piston, thereby forcing the brake pad on the opposite side of the piston to engage the rotor. As pressure is built up behind the piston, it forces the brake pads tighter against the rotor to develop additional braking force.
Figure 1-9. Floating caliper
d. Fixed calipers. Fixed calipers (Figure 1-10) are mounted firmly to the spindle or splash shield. In this design, the caliper is usually made in two pieces and has two, three, or four pistons in use. The pistons, which may be made of cast iron, aluminum, or plastic, are provided with seals and dust boots and fit snugly in bores machined in the caliper. The pistons accomplish the centering action of the fixed caliper as they move in their bores. If the lining wears unevenly on one side of the caliper, the piston would take up the excess clearance by simply moving farther out in its bore. As the brakes are applied, the fluid pressure enters the caliper on one side and is routed to the other side through an internal passageway or an external tube connected to the opposite half of the caliper. As pressure is increased, the piston forces the brake pads against the rotor evenly and the pistons maintain an equal amount of pressure on both sides of the rotor.

e. Multipiston designs. Fixed calipers use a multipiston design to provide the braking force. The fixed caliper may be designed to use two, three, or four pistons as shown in Figure 1-10. The dual-piston design provides a slight margin of safety over a single-piston floating caliper. If a piston seizes in the caliper, the single-piston caliper would be rendered useless, while the dual-piston design would still have one working piston to restore some brake ability. The three- and four-piston design provides for the use of a larger brake lining. The brake force developed may be spread over a larger area of the brake pad.

1-7. Mechanical Brakes. On wheeled vehicles, the energy supplied by the operator's foot while pushing down on the brake pedal is transferred to the brake mechanism on the wheels by various means. A mechanical hookup has been used since the earliest motor vehicles, but mechanical-operated brake systems are practically obsolete now. However, mechanical hookups are still used for a portion of the braking system.

1-8. Parking Brakes. The parking brake is designed to keep a vehicle stationary when it is parked. The parking brake can be used to stop a vehicle in an emergency if the service brakes fail. For this reason, the parking brake is sometimes referred to as the emergency brake. The brake in vehicles with a hydraulic system operates mechanically on the transmission, the transfer case, or the brake shoes of the rear wheels. When the hand brake operates on the rear wheels, it is usually linked to the same shoes that are operated by the hydraulic pistons. Toggle leverage is used to apply the shoes. With this arrangement, the hand lever applies the shoes either hydraulically by the brake pedal or mechanically. In normal operation, the braking action is entirely one of hydraulic force with the mechanical hookup working in connection with the hydraulic system. With the correct amount of fluid in the lines and the brakes properly set, the mechanical hookup is inactive. If the hydraulic system fails, the mechanical linkage acts as a safeguard.
Figure 1-10. Fixed and multipiston calipers
LESSON 1

PRACTICE EXERCISE

The following items will test your grasp of the material covered in this lesson. There is only one correct answer for each item. When you complete the exercise, check your answer with the answer key that follows. If you answer any item incorrectly, study again that part of the lesson which contains the portion involved.

1. Which of the following is used to slow or stop a vehicle?
   
   A. Friction  
   B. Momentum  
   C. Inertia  
   D. Heat

2. Which of the following metals are used to make brake drums?
   
   A. Pressed steel, cast iron, or a combination of two metals, or aluminum  
   B. Cast iron and cast aluminum  
   C. Cast aluminum and pressed steel  
   D. Rolled steel and copper

3. What action is taken when a brake drum is badly scored or the drum is out of round?
   
   A. Replace the brake shoes  
   B. Replace the drum  
   C. Machine the brake drum  
   D. Reverse the brake shoes

4. Which of the following metals are cheaper to use when making brake shoes?
   
   A. Malleable iron  
   B. Cast iron  
   C. Pressed steel  
   D. Cast aluminum

5. What type of rivets are used to attach the brake linings to the brake shoes?
   
   A. Brass  
   B. Iron  
   C. Steel  
   D. Aluminum
6. What are the two types of brake linings?
   A. Copper and fiber
   B. Molded and woven
   C. Asbestos and cotton
   D. Asbestos and fiber

7. What is the primary function of a brake-drum assembly?
   A. To force the brake drum outward
   B. To decrease the amount of braking effort on the brake drum
   C. To dissipate the heat generated by friction on the brake drum
   D. To force the brake shoe against the rotating brake drum

8. Which of the following is an advantage of self-energizing brakes?
   A. Smoother brake action
   B. Reduced amount of effort required to achieve a given amount of retardation
   C. Decreased tendency to skid on sudden stops
   D. Decreased brake fade

9. Which of the following is an advantage of disk brakes?
   A. Less prone to brake fade
   B. Self-energizing
   C. Less expensive
   D. Easy to adjust

10. What are the two types of brake calipers?
    A. Floating and fixed
    B. Free and stationary
    C. Rotating and wedge
    D. Floating and attached
## LESSON I

### PRACTICE EXERCISE

### ANSWER KEY AND FEEDBACK

<table>
<thead>
<tr>
<th>Item</th>
<th>Correct Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>A. Friction</td>
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<td>Each of these units has braking . . . (page 1-2, para 1-2)</td>
</tr>
<tr>
<td>2.</td>
<td>A. Pressed steel, cast iron, or a combination of two metals, or aluminum</td>
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<td>Brake drums are made of... (page 1-5, para 1-4)</td>
</tr>
<tr>
<td>3.</td>
<td>C. Machine the brake drum</td>
</tr>
<tr>
<td></td>
<td>When the surface is scored ... (page 1-7, para 1-4c)</td>
</tr>
<tr>
<td>4.</td>
<td>C. Pressed steel</td>
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<td>Pressed steel is commonly used .. (page 1-7, para 1-5a)</td>
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<tr>
<td>5.</td>
<td>A. Brass</td>
</tr>
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<td></td>
<td>Brass rivets are chosen ... (page 1-8, para 1-5b)</td>
</tr>
<tr>
<td>6.</td>
<td>B. Molded and woven</td>
</tr>
<tr>
<td></td>
<td>Brake linings come in molded and woven types. (page 1-8, para 1-5c)</td>
</tr>
<tr>
<td>7.</td>
<td>D. To force the brake shoe against the rotating brake drum</td>
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<td></td>
<td>The primary function of the brake ... (page 1-3, para 1-3)</td>
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<tr>
<td>8.</td>
<td>B. Reduced amount of effort required to achieve a given amount of retardation</td>
</tr>
<tr>
<td></td>
<td>This effect on the brake . . (page 1-3, para 1-3a)</td>
</tr>
<tr>
<td>9.</td>
<td>A. Less prone to brake fade</td>
</tr>
<tr>
<td></td>
<td>This feature makes the ... (pages 1-10, para 1-6b)</td>
</tr>
<tr>
<td>10.</td>
<td>A. Floating and fixed</td>
</tr>
<tr>
<td></td>
<td>Floating caliper and fixed caliper. (page 1-10 through 1-12, para 1-6c and 1-6d)</td>
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</tbody>
</table>
LESSON 2
HYDRAULIC BRAKE SYSTEMS

Critical Tasks: 091-62B-1005
091-62B-3054

OVERVIEW

LESSON DESCRIPTION:

After completing this lesson, you will understand the principles of hydraulic brake systems and how to troubleshoot, adjust, and repair a hydraulic brake system on a SEE.

TERMINAL LEARNING OBJECTIVE:

ACTION: You will learn the principles of hydraulic brake systems.

CONDITION: You will be given the material contained in this lesson.

STANDARD: You will correctly answer practice exercise questions at the end of this lesson.

REFERENCES: The material contained in this lesson was derived from TMs 5-2420-224-20-1, 5-2420-224-20-2, and 9-8000.

INTRODUCTION

Hydraulics is the study of liquids in motion or the pressure exerted by liquids that are conveyed in pipes or conduits. In a hydraulic brake system, pressure applied at the brake pedal is transmitted to the brake mechanism by a liquid. To better understand how pressure is transmitted by a hydraulic brake system, it is necessary to understand the principles of hydraulics. Two well-known hydraulic principles are liquid compression and liquid distribution.

PART A - PRINCIPLES

2-1. Compression. Liquids cannot be compressed under ordinary pressures, and this may be demonstrated by placing a weight on top of a piston fitted to a jar (Figure 2-1, page 2-2). The
force of the weight does not change the level of the liquid; therefore, it does not diminish the volume or compress the liquid.

Figure 2-1. Noncompressibility of liquids

2-2. Distribution. Force that is exerted at any point upon a confined liquid is distributed equally through the liquid in all directions. That is, if a total force of 20 pounds, including the piston and the weight, is placed upon liquid in a jar and the piston in the jar has an area of 5 square inches, the unit hydraulic pressure is increased by 20 to 5, or 4 pounds per square inch (psi). This is shown in Figure 2-2. A gauge inserted at any point in the jar will indicate a pressure of 4 psi, since the liquid transmits the pressure equally throughout the jar.

2-3. Illustration. The use of hydraulic principles may be illustrated by interconnecting two jars of the same diameter that contain liquid (Figure 2-3). If force is exerted on the piston in one jar (the left jar in Figure 2-3), the piston in the other jar will receive the same amount of force due to the transmission of pressure by liquid. When the areas of the two pistons are equal, moving one piston produces an identical movement of the other piston because the liquid is not compressible and therefore maintains the same volume. The following paragraphs contain more illustrations of hydraulic principles.

a. Two jar illustration. By connecting two jars together, the second jar having twice the diameter of the first and therefore four times the area. The results are somewhat different, although the same facts apply (Figure 2-4, page 2-4). When force is exerted on the piston in the small jar, the piston in the large jar will receive four times as much force because the hydraulic pressure acts on four times the area. Since liquid will always occupy the same volume, the large piston will move one-fourth as far as the small piston.
b. Four jar illustration. With four jars of the same diameter connected to a central jar (Figure 2-5, page 2-4), an approximation of the action in four wheel brakes is obtained. Force that is exerted on the piston in the central jar will be transmitted to each of the other jars so that the piston in each jar will receive an identical force but will move only one-fourth as far as the central piston. If the four jars have a larger diameter than the central jar, the total pressure on each of the four pistons is greater than that applied to the central one, and each of the four pistons moves less than one-fourth as far as the central piston. Hydraulic brake systems operate in such a manner.

![Figure 2-2. Equal distribution of force on confined liquid](image)

![Figure 2-3. Distribution of force in a hydraulic system using the same-size pistons](image)
Figure 2-4. Distribution of force in a hydraulic system using different-size pistons

Figure 2-5. Four jars connected to a central jar
2-4. **Operation.** In a hydraulic brake system, force is applied to the piston in a master cylinder. The brake pedal operates the piston by linkage and each wheel brake has a cylinder (Figure 2-6). Inside the cylinder are opposed pistons that are connected to the brake shoes. When the brake pedal is depressed, it moves the piston within the master cylinder, forcing the brake fluid from the master cylinder through the tubing and flexible hose into the four wheel cylinders.

![Hydraulic brake system diagram](image)

**Figure 2-6. Hydraulic brake system**

a. **Fluid type.** All hydraulic brake systems use silicone brake fluid. Silicone brake fluid does not freeze or boil at temperatures encountered in year-round operation of the construction equipment.

b. **Fluid flow.** Brake fluid enters each of the wheel cylinders between the opposed pistons, making the pistons move the brake shoes outward against the brake drum. As pressure on the pedal is increased, more hydraulic pressure is built up in the wheel cylinders and more force is exerted against the ends of the brake shoes.

c. **Brake release.** When the pressure on the pedal is released, retracting springs on the brake shoes pull the shoes away from the drum. This forces the wheel-cylinder pistons to release their positions and forces the brake fluid back through the flexible hose or tubing to the master cylinder.

2-5. **Master Cylinder (Power Conversion).** The master cylinder (Figure 2-7, page 2-6) is the primary unit in the brake system that converts the force of the driver's foot into fluid pressure to operate the wheel brake cylinders. The master-cylinder housing is an aluminum or iron casting that may have an integral reservoir, which is usually a detachable nylon or steel reservoir. The reservoir carries sufficient reserve fluids to allow for expansion and contraction of brake fluid and allow for brake-lining wear. The reservoir is filled to the top and is well sealed by a
removable filler cap containing a vent. The master cylinder usually is mounted to the fire wall, which allows for easy inspection and service and is less prone to dirt and water.

![Diagram of master cylinder]

**Figure 2-7. Master cylinder**

a. **Construction.** The master-cylinder piston is a long, spool-like member with a rubber secondary cup seal at the outer end. It has a rubber primary cup, which acts against the brake liquid just ahead of the inner end. The primary cup is kept against the end of the piston by a return spring. The inner-piston head has several small bleeder ports that pass through the head to the base of the rubber primary cup. A steel, stop disk, held in the outer end of the cylinder by a retaining spring (snap ring), acts as a piston stop. A rubber boot covers the piston end of the master cylinder. This boot is vented to prevent air from being compressed within it.

b. **Operation.** In the outlet end of the cylinder, there is a combination inlet and outlet check valve that is held in place by the piston return spring. This check valve is a little different from most check valves that let fluid pass through them in one direction only. If enough pressure is applied to this valve, fluid can go in or around it in either direction. This means it will keep some pressure in the brake lines. The check valve consists of a rubber valve cup in a steel valve case. This assembly rests on a rubber valve seat that fits in the end of the cylinder. In some designs, the check valve consists of a spring-operated outlet valve that is seated on a valve cage rather than a rubber cup outlet valve; but the principle of operation is the same. The piston
return spring normally holds the valve cage against the rubber valve seat to seal the brake fluid in the brake line.

2-6. **Wheel Cylinder.** The wheel cylinder (Figure 2-8) changes hydraulic pressure into mechanical force. This pushes the brake shoes against the drum.

   a. **Operation.** The wheel-cylinder housing is mounted on the brake's backing plate. Inside the cylinder are two pistons that are moved in opposite directions by hydraulic pressure and, at the same time, push the shoes against the drum.

   ![Figure 2-8. Wheel cylinder](image)

   b. **Description.** The pistons or piston stems are connected directly to the shoes. Rubber piston cups fit in the cylinder bore against each piston to prevent the escape of brake fluid. Light springs between the cups keep the cups in position against the pistons. To keep out foreign matter, the open ends of the cylinder are fitted with rubber boots. Brake fluid enters the cylinder from a brake-line connection between the pistons. At the top of the cylinder, between the pistons, there is a bleeder hole and a screw through which air is released when the system is being filled with brake fluid.

   c. **Cause and effect.** Due to the self-energizing action on some vehicles, a stepped wheel cylinder (Figure 2-9, page 2-8) is used to compensate for the faster rate of wear on the front shoe than on the rear shoe. By using a larger piston for the rear shoe, the shoe receives more pressure to offset the self-energizing action of the front shoe. If it is desired that both shoes be independently self-energizing, it is necessary to have two wheel cylinders, one for each shoe. Each cylinder has a single piston and is mounted on the opposite side of the brake-backing plate from the other cylinder.
2-7. Brake Operation. Previous paragraphs have discussed the parts that make up a hydraulic brake system. To illustrate what happens to these parts when the brakes are applied and released, assume that the master cylinder is installed on a vehicle and the hydraulic system is filled with fluid. As the operator pushes down on the brake pedal, the linkage moves the piston in the master cylinder. As the piston moves inward, the primary cup seals off the bypass port (sometimes known as the compensating port).

   a. Bypass port closed. With the bypass port closed, the piston traps the fluid that is ahead of it and creates pressure in the cylinder. This pressure forces the check valve to open, and fluid passes into the brake line. The piston continues to move and forces fluid through the line into the wheel cylinders. Hydraulic pressure causes the wheel-cylinder pistons to move outward and forces the brake shoe against the brake drum. As long as pressure is kept on the brake pedal, the brake shoes will remain pressed against the brake drum.

   b. Brake pedal released. When the brake pedal is released, the pressure of the linkage or pushrod is removed from the master-cylinder piston. The return spring pushes the piston back to the released position and reduces the pressure in front of the piston. The check valve slows the sudden return of fluid from the wheel cylinders. As the piston moves toward the released position in the cylinder, fluid from the master-cylinder supply tank flows through the in port and then through the bleeder holes in the head of the piston. This fluid will bend the primary cup's lips away from the cylinder wall, and the fluid will flow into the cylinder ahead of the piston. When the pressure drops in the master cylinder, the brake-shoe return springs will pull the shoes away from the drum. As the shoes are pulled away from the drum, the shoes squeeze the wheel-cylinder pistons together, thus forcing the brake fluid to flow back into the master cylinder. The returning fluid forces the check valve to close. The entire check valve is then forced off its seat. The fluid then flows into the master cylinder around the outer edges of the valve. When the
piston in the master cylinder has returned to its released position against the stop plate, the primary cup uncovers the bypass port and any excess fluid flows through the bypass port to the reservoir. This prevents the brakes from "locking up" when the heat of the brakes causes the brake fluid to expand.

c. Cycle repeated. The check valve seats when the pressure of the piston return springs is more than the pressure of the return fluid. The valve will keep a slight pressure in the brake line and wheel cylinders. The brake system is now in position for the next brake application.

PART B - TROUBLESHOOTING

2-8. Introduction. This part provides information required for diagnosing and correcting the unsatisfactory operation or the failure of a hydraulic brake system on an item of engineer construction equipment. A job situation has been created that requires the use of Department of Army (DA) Form 5988-E (Figure 2-10, page 2-10), a troubleshooting guide (Appendix D, pages D-3 through D-13), and a maintenance allocation chart (Appendix D pages D-14 through D-15). The SEE tractor will be used for the job situations.

2-9. Requirement. The requirement for each situation is to diagnose the problem, take appropriate corrective action, and complete the DA Form 5988-E. For all situations you will be a sergeant (E-5), heavy construction repairman (62B20), assigned to B Company, 88th Engineer Battalion (Combat Heavy), Fort Chaos, Kansas. You are the senior construction-equipment repairer in the maintenance section, and you will have an operator available for assistance. Safety is a prime consideration. Ensure that the engine is shut off, all control and transmission levers are in the neutral position, the parking brake is set, and the wheels are chocked.

2-10. Initial Situation. You have received a DA Form 5988-E (Figure 2-10) with instructions to troubleshoot the hydraulic brake system. After obtaining your assigned toolbox and a copy of TM 5-2420-224-20-1, proceed to where the operator is standing by with the SEE. The most logical place to begin the troubleshooting process is to talk to the SEE operator. The operator relates that he was in the process of moving the SEE from its assigned parking position to the equipment washrack. When he reached the washrack, he attempted to stop the SEE with the service brakes. After repeatedly pushing the brake pedal without results, he had to use the parking brake to make an emergency stop. Ensuring that you observe all safety restrictions, your next step is to personally check the SEE's operation. Since there is no traffic in the general area, operate the SEE in both forward and reverse gears and verify that the wheel brakes will not stop the SEE. Using the parking brake, ease the SEE to a hardstand. Since there is no other indication of why the brakes failed, you should perform a visual inspection. Use the following paragraphs to determine what actions should be taken:
Figure 2-10. Sample DA Form 5988-E

a. Interpret inspection data. Refer to Appendix D, page D-3, paragraphs 83 and 84. Follow steps 1 through 5 below to perform this task:

<table>
<thead>
<tr>
<th>Item Operation Number</th>
<th>Fault Date</th>
<th>Fault Status</th>
<th>Fault Description</th>
<th>Corrective Action</th>
<th>Hours</th>
<th>License Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 Aug 96 X</td>
<td>Service brakes will not stop when applied</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Step 1. Interpret the fault-status symbol indicated on DA Form 5988-E (see Figure 2-10). Four symbols may appear in this column. Each one indicates a different fault status. Use Table 2-1 to define the symbols.

**Table 2-1, Fault-status symbols**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>/</td>
<td>This symbol indicates that there is a deficiency and the vehicle may be operated.</td>
</tr>
<tr>
<td>⊗</td>
<td>This symbol indicates that the vehicle may be used for limited operations.</td>
</tr>
<tr>
<td>X</td>
<td>This symbol indicates that the vehicle is in an inoperative status.</td>
</tr>
<tr>
<td>—</td>
<td>This symbol indicates that there is an inspection component replacement, or an overdue maintenance work order has not been applied.</td>
</tr>
</tbody>
</table>

Based on the fault-status symbol shown in Figure 2-10, page 2-10, and Table 2-1, the X indicates that the brakes are in an inoperative status.

Step 2. Use a troubleshooting guide when inspecting an unserviceable piece of equipment. The guide helps narrow down the possible causes for each discrepancy, instruct on any other checks that must be made, and determine where to go next to correct the problem.

Problem: Refer to Appendix D, page D-3, paragraphs 83 and 84. Following the inspection, determine which paragraph (83 or 84) best describes the fault status stated on DA Form 5988-E.

Solution: Determine the correct answer. Paragraph 83 (step 1) is the correct answer.

Step 3. Continue with a visual inspection of the SEE and make the following notes. This paragraph presents the most possible causes for wheel-brake failure in this situation.

- The brake-fluid level in the reservoir is full.
- There are no leaking lines.
- There are no damaged fittings.
- There is no air when bleeding the brake system.

Step 4. Refer to Appendix D, page D-3, paragraphs 83 and 84. Determine the most probable cause and solution for the brake failure by comparing your notes with the steps in paragraph 83.
Problem: Which is the correct solution for the brake-failure problem?

A. Add silicone brake fluid.
B. Tighten or replace the brake lines and fittings.
C. Bleed the brake system.
D. Replace the brake master cylinder.

Solution: Based on the findings, D is the correct answer. When reporting these findings to the maintenance supervisor, you are instructed to determine the level of maintenance needed for the replacement or repair of the master cylinder.

Step 5. Refer to Appendix D, pages D-14 and D-15, to determine the appropriate level of maintenance by locating the appropriate level in column 4.

Problem: Which maintenance level authorizes the replacement of the master cylinder?

A. C (crew)
B. O (organization)
C. F (direct support)
D. H (general support)
E. D (depot)

Solution: The correct answer is B. Based on this answer, the maintenance supervisor assigns you the task of replacing the master cylinder.

b. Remove and reinstall the master cylinder. In preparation for this task, the outside engine hood was removed, the wheels were chocked, and the parking brake was set. Suitable containers are available to catch the brake fluid. Use the following steps to remove and reinstall the master cylinder (refer to Figure 2-11):

Step 1. Tag the lines before disconnecting them to aid in reconnecting them.

Step 2. Disconnect the brake-fluid reservoir hose (1) and the clutch hydraulic reservoir hose (2). Drain each hose in a suitable container.

Step 3. Use a wrench to disconnect the two brake-line fittings (3 and 4).

Step 4. Remove the three screws (5), the three spring-tension washers (6), and the brake master cylinder (7). Discard the three spring-tension washers.

Step 5. Remove the two bleeder valves (8 and 9).

Step 6. Reinstall the two bleeder valves (8 and 9).

Step 7. Reinstall the brake master cylinder by installing the two bleeder valves (8 and 9).
Step 8. Install the brake master cylinder (7), the three screws (5), and the three new spring-tension washers (6).

Step 9. Use a wrench to connect the two brake-line fittings (3 and 4).

Step 10. Connect the two hoses (1 and 2).

Step 11. Fill the clutch hydraulic reservoir according to lubrication order (LO) 5-2420-224-12.

Step 12. Fill the brake-fluid reservoir according to LO 5-2420-224-12.

c. Bleed the brake system. Following the installation of the master cylinder, the next task is to bleed the brake system. Bleeding the brake system by pumping the brake pedal is not sufficient. Compressed air (regulated to 14.5 to 29 psi [1-2 bar]) must be used to bleed the brake system to prevent damage to the equipment. Do not reuse the brake fluid as it is considered contaminated and could damage the equipment. Follow steps 1 through 13 below (Figure 2-12, page 2-14) to bleed the brake system:
Step 1. Remove the two brake-fluid reservoir caps (1 and 2) from the two brake-fluid reservoirs (3 and 4).

Step 2. Install the two elbows (6) on the hose (5).

Step 3. Install the adapter assembly (9) to the two brake fluid reservoirs (7 and 8).

Step 4. Connect the adapter assembly (9) to the air supply hose (10). Remember to—

- Use a suitable container to catch the brake fluid.

Figure 2-12. Brake system bleeding
• Open only one bleeder valve at a time.

• Observe the fluid level in the brake-fluid reservoirs and do not allow the brake fluid to go below the MIN indicator before adding more fluid to the reservoir.

Step 5. Bleed the brake system in the following order:

• Master cylinder (11) in two places,
• Right-rear caliper (12).
• Left-rear caliper (13).
• Right-front caliper (14).
• Left-front caliper (15).
• Antilock brake modulator (16).
• Right-front caliper (17).
• Left-front caliper (18).
• Clutch-slave cylinder (19).

NOTE: The brake system is considered to be properly bled when a steady stream of brake fluid, with no air bubbles, comes out of the bleeder valve.

Step 6. Disconnect the air-supply hose (10) from the adapter assembly (9).

Step 7. Remove the adapter assembly (9) from the two brake-fluid reservoirs (7 and 8).

Step 8. Remove the two elbows (6) from the hose (5).

Step 9. Fill the two brake-fluid reservoirs (7 and 8) to the MAXX indicator with brake fluid.

Step 10. Install the two brake-fluid reservoir caps (1 and 2) on the two brake-fluid reservoirs (3 and 4).

Step 11. Fill the clutch hydraulic reservoir according to LO 5-2420-224-12.

Step 12. Fill the brake-fluid reservoir according to LO 5-2420-224-12.

Step 13. Install the outside engine hood.
d. Adjust the brake pedal. The brake pedal requires adjustment at this stage of the task. Refer to Figure 2-13 while using the following steps to adjust the brakes:

Step 1. With the brake pedal (1) at neutral, the piston-rod clearance must be 0.04 inch (1 millimeter).

Step 2. If the measurement is not within tolerance, adjust the clearance by turning the eccentric screw (2).

Figure 2-13. Brake-pedal adjustment
LESSON 2

PRACTICE EXERCISE

The following items will test your grasp of the material covered in this lesson. There is only one correct answer to each item. When you complete the exercise, check your answer with the answer key that follows. If you answer any item incorrectly, study again that part of the lesson which contains the portion involved.

1. The wheel cylinder changes hydraulic pressure into what type of force?
   A. Hydraulic
   B. Mechanical
   C. Electrical
   D. Centrifugal

2. A stepped wheel cylinder is used on the front and rear shoes to compensate for what rate of wear?
   A. Faster
   B. Slower
   C. Equal
   D. Unequal

3. The liquid used in a hydraulic brake system is known as__________________.
   A. Hydraulic fluid
   B. Brake fluid
   C. OE-10
   D. GO-90

4. What status symbol would be shown on DA Form 5988-E if the brakes were inoperative?
   A. /
   B. ⊗
   C. X
   D. ─

5. Which is the primary unit in the brake system that converts the force of the driver's foot into fluid pressure for operating the wheel cylinders?
   A. Linkage
   B. Brake line
   C. Brake fluid
   D. Master cylinder
6. After verifying a status fault, which of the following sources is used to determine the maintenance level?

A. Maintenance supervisor
B. Troubleshooting guide
C. Maintenance allocation chart
D. DA Form 5988-E

7. The most logical place to begin the troubleshooting process is with the

A. DA Form 5988-E
B. Troubleshooting guide
C. Maintenance supervisor
D. Operator

8. When replacing a master cylinder, what additional item must be replaced as well?

A. Brake hoses
B. Bleeder valves
C. Spring-tension washers
D. Reservoir caps

9. Pumping the pedal is not sufficient when bleeding the brake system. To prevent damage to the equipment, compressed air is used to bleed the brake system. How much air should be used?

A. 18 to 20 psi
B. 15 to 25 psi
C. 14.5 to 45 psi
D. 14.5 to 29 psi

10. Which substance should be missing from a steady stream of brake fluid that is coming out of a properly bled brake system?

A. Oil
B. Silicone
C. Bubbles
D. Hydraulic fluid
## LESSON 2

### PRACTICE EXERCISE

**ANSWER KEY AND FEEDBACK**

<table>
<thead>
<tr>
<th>Item</th>
<th>Correct Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>B. Mechanical</td>
</tr>
<tr>
<td></td>
<td>The wheel cylinder changes...(page 2-7, para 2-6)</td>
</tr>
<tr>
<td>2.</td>
<td>A. Faster</td>
</tr>
<tr>
<td></td>
<td>Due to the self-energizing action...(page 2-7, para 2-6c)</td>
</tr>
<tr>
<td>3.</td>
<td>B. Brake fluid</td>
</tr>
<tr>
<td></td>
<td>All hydraulic brake systems...(page 2-5, para 2-4a)</td>
</tr>
<tr>
<td>4.</td>
<td>C. X</td>
</tr>
<tr>
<td></td>
<td>Table 2-1 (page 2-11, para 2-10a, step 1)</td>
</tr>
<tr>
<td>5.</td>
<td>D. Master cylinder</td>
</tr>
<tr>
<td></td>
<td>The master cylinder is the ...(page 2-5, para 2-5)</td>
</tr>
<tr>
<td>6.</td>
<td>C. Maintenance allocation chart</td>
</tr>
<tr>
<td></td>
<td>Refer to Appendix D...(page 2-12, para 2-10a, step 5)</td>
</tr>
<tr>
<td>7.</td>
<td>D. Operator</td>
</tr>
<tr>
<td></td>
<td>The most logical place to begin ...(page 2-9, para 2-10)</td>
</tr>
<tr>
<td>8.</td>
<td>C. Spring-tension washers</td>
</tr>
<tr>
<td></td>
<td>Install the brake...(page 2-13, para 2-10b, step 8)</td>
</tr>
<tr>
<td>9.</td>
<td>D. 14.5 to 29 psi</td>
</tr>
<tr>
<td></td>
<td>Compressed air (regulated to...(page 2-13, para 2-10c)</td>
</tr>
<tr>
<td>10.</td>
<td>C. Bubbles</td>
</tr>
<tr>
<td></td>
<td><strong>NOTE: The brake system is considered</strong> ...(page 2-15, para 2-10c, step 5)</td>
</tr>
</tbody>
</table>
LESSON 3

COMPRESSED-AIR BRAKE SYSTEMS

Critical Tasks: 091-62B-1005
091-62B-3054

OVERVIEW

LESSON DESCRIPTION:

In this lesson, you will understand the principles of the compressed-air brake system and how to troubleshoot, adjust, and repair this system on a Harnischfeger Model MT 250 crane.

TERMINAL LEARNING OBJECTIVE:

ACTION: You will learn the principles of compressed-air brake systems.

CONDITION: You will be given the material contained in this lesson.

STANDARD: You will correctly answer practice exercise questions at the end of the lesson.

REFERENCES: The material contained in this lesson was derived from TMs 5-3810-293-14&P1 and 9-8000.

INTRODUCTION

The pressure applied at the brake pedal is transmitted to the brake mechanism by air. To better understand how pressure is transmitted by an air brake system, it is necessary to understand the principles of compressed gasses.

PART A - PRINCIPLES AND BASIC COMPONENTS

3-1. Principles. The principle characteristic of an air brake system is that the brakes, although controlled by the operator, are applied by compressed air. Compressed air provides enough braking force to control even the heaviest vehicle. Unlike liquids, gasses are compressed easily. If a gas, such as air, is confined and a force is applied to it, the gas is compressed and has less
volume (Figure 3-1). Placing a weight on a piston that fits into a container may exert such a force. The air that originally filled the entire container is pressed into only a portion of the container due to the force of the weight upon it. The pressure of the compressed air, resulting from the force exerted on it by weight, will be equally distributed in all directions just as it is in a liquid. Compressed air under pressure may be stored conveniently and made available for the power application of brakes. An air line connects the compressed air in the air reservoirs to the brake valve. The brake pedal operates the lever on the brake valve. When the brake pedal is depressed, it opens a valve in the brake valve and measures a certain amount of compressed air from the air reservoirs to go to the front and rear axles.

![Figure 3-1. Gas compressibility](image)

3-2. **Basic Components.** The compressed air brake system consists of eight components (Figure 3-2). They are the—

- Compressor.
- Reservoirs.
- Governor.
- Brake valve.
- Brake chambers.
- Quick-release valve.
• Relay valve.
• Slack adjusters.

This system is similar to the hydraulic brake systems in Lesson 2. There may be some minor differences in the compressor and the governor, but they will not affect the maintenance practices on the components. A pump or compressor driven by the engine is used to compress air and force it into a reservoir, where it is forced under pressure and made available for operating the brakes. Air under pressure in the reservoir is released to the brake lines by a valve operated by the brake pedal. This released air goes to the brake chambers (near the wheel brakes), which contain a flexible diaphragm. A plate against the diaphragm is connected directly to the mechanism on the wheel brakes by linkage. The force of the compressed air admitted to the chamber causes the diaphragm to move the plate and operate the brake shoes through the linkage. Special regulating valves operate brakes on all vehicles and trailers.

Figure 3-2. Compressed-air brake system and components
a. Air compressor and air reservoir. The air compressor furnishes compressed air for brake operations. It is driven directly from the engine crankshaft or from one of the auxiliary shafts. The air reservoir receives air from the compressor and stores it for use in the brake system.

(1) Description. Air compressors are usually single-acting reciprocating units, either self-lubricated or lubricated from the vehicle engine's lubricating system. Both water-cooled and air-cooled cylinder heads are used. Air compressors with a displacement of approximately 7 cubic feet per minute (cfm) have two cylinders, while those with a displacement of 12 cfm have three cylinders. A typical air compressor is shown in Figure 3-3.

![Figure 3-3. Typical air compressor](image)
(2) Operation. Air compressors operate continuously while the engine is running, but the governor controls the actual compression of air. With a partial vacuum created on the piston downstroke, intake ports are uncovered near the bottom of the stroke. Intake ports are covered as the piston starts its upstroke, and air in the cylinder is compressed. The pressure lifts the discharge valve, and the compressed air is discharged to the reservoirs. When the piston starts its downstroke, the discharge valve closes as soon as the pressure is relieved. When the reservoir air pressure reaches the maximum setting of the governor, air under pressure is allowed to pass into a cavity below an unloading diaphragm in the cylinder head. This air pressure lifts one end of the unloading lever, which pivots on its pin and forces the unloading valves off their seats. With the unloading valves off their seats, an unloading cavity forms a passage between the cylinders and the compression is stopped. A drop in air pressure below the minimum setting of the governor causes the unloading valves to release the air pressure from beneath the unloading diaphragm. The unloading valves return to their seats, and compression is resumed.

b. Air governor. This component limits the pressure produced by the compressor.

(1) Description. The air governor (Figure 3-4) maintains the air pressure in the reservoir by controlling the compressor-unloading mechanism.

(2) Operation. A gear-driven air compressor mounted on an engine supplies air pressure for the brake system. Compressed air is stored in interconnected metal tanks. Pressure produced by the compressor is controlled by the air governor, which controls the operation of the compressor. The air governor is set to regulate the pressure in the air system at 100 psi. When air use drops the pressure, the air governor is actuated to cause the air compressor to build up the set pressure.
c. Air brake valve. This component controls the brake operation. It directs the flow of air from the reservoir to the air brake chambers when the brakes are applied and from the air brake chambers to the atmosphere when the brakes are released.

(1) Description. The air brake-valve lever is connected to the brake pedal. The lever controls the operation of the inlet and exhaust valves (Figure 3-5). These valves control the air that is delivered to or released from the brake chamber.

(2) Operation. When the brake pedal is depressed, the air brake-valve lever moves toward its applied position. The plunger and the regulating spring are forced down, applying mechanical force on the diaphragm. The exhaust-valve spring is weaker than the intake-valve spring, so the exhaust valve is forced downward onto its seat before the intake valve is opened. When the intake valve opens, air from the reservoir is allowed to flow through the air brake valve to the air brake chambers to apply the brakes. When the air pressure below the diaphragm overcomes the mechanical force exerted on top of the diaphragm, the diaphragm lifts enough to close the intake valve and maintain a constant air pressure in the system. Further depression of the pedal puts additional mechanical force on the diaphragm, thereby allowing further brake application. If the operator releases the brake pedal, reducing the mechanical force on the diaphragm, the inlet valve remains closed while the exhaust valve opens to allow the air to be exhausted from the air brake chambers to release the brakes.

Figure 3-5. Air brake valve
d. Air brake chambers. These components (one for each wheel) are used to convert the pressure of the compressed air into mechanical force for applying the brakes.

(1) Description. An air brake chamber (Figure 3-6) at each wheel converts air pressure to mechanical motion.

(2) Operation. Air under pressure enters an air brake chamber behind the diaphragm. The diaphragm compresses the return spring, causing the pushrod to travel. The slack adjuster rotates and turns the camshaft. An S-cam connected to the end of the camshaft turns and pushes the brake shoe assemblies apart, causing the brakes to apply.

Figure 3-6. Air brake chamber

e. Air quick-release valve. This component is used to speed up the exhaust of the air brake chambers, so that all the brakes may be quickly released. The chambers are not close to the brake valve.

(1) Description. The valve (Figure 3-7, page 3-8) is an air line that goes from the brake valve to the front axle. The air quick-release valve is provided to reduce the time required to release the brakes by slowing the exhaust of air under pressure from the air brake chambers.
(2) Operation. The valve contains a spring-loaded diaphragm that allows airflow through the valve in only one direction. In the brake-application piston, air that is under pressure from the brake valve enters the inlet port. The diaphragm is forced downward and closes the exhaust port. The air that is under pressure then deflects the outer edges of the diaphragm downward and enters the brake chambers to apply the brakes. When the air pressure in the chambers and below the diaphragm equals the air pressure above the diaphragm, the diaphragm spring forces the outer edge of the diaphragm up against the valve body, closing the brake chambers for the inlet port. In this holding position, the diaphragm continues to keep the exhaust valve closed. If the pressure above the diaphragm is reduced or is completely released by the operator releasing the brake pedal (partially or completely), the air pressure below the diaphragm causes the diaphragm to raise opens the exhaust port, and releases the brake chamber's air pressure.

![Diagram of Air Quick-Release Valve](image)

**Figure 3-7. Air quick-release valve**

f. Air relay valve. This component is used to speed the operation of the rear wheel brakes on trailers and trucks with long wheelbases. Shorter brake lines permit rapid brake action without the aid of a relay valve on trucks with short wheelbases.

(1) Description. An air line connects the brake valve to the air relay valve (Figure 3-8) located at the rear of the vehicle. Normally, this line also contains the stoplight switch. A second air line supplies reservoir air pressure to the air relay valve. The air relay valve is controlled by the brake valve and speeds up application and release of the rear wheel brakes.
for long wheelbase vehicles. It reacts quickly to slight changes in air pressure from the air brake valve.

(2) Operation. When the brake pedal is depressed, the brake valve meters a certain amount of air to the relay valve. This air opens a valve in the air relay valve and allows a small amount of air from the air reservoir to go to each of the air brake chambers for the rear wheels. When the brake pedal is released, air pressure in the line between the brake valve and the relay valve is released. This closes the valve in the air relay valve, shutting off the air supply from the air reservoir. At the same time, an air quick-release valve in the relay valve opens and allows the air pressure in the air brake chambers to escape. This, in turn, releases the rear brakes. The air in the line from the brake valve escapes from the brake valve's exhaust valve. The amount of braking action applied to the truck wheels depends on how far down the brake pedal is depressed. When the pedal is pressed down, a greater amount of air pressure is applied to the air brake chambers. This causes the brake shoes and linings to press harder against the brake drums and provides a greater braking action.

Figure 3-8. Air relay valve
g. Slack adjuster. This component is used to adjust the brakes to compensate for lining wear.

(1) Description. The slack adjuster functions as an adjustable lever and provides a means of adjusting the brakes. The pushrod of the air brake chamber is connected to a slack adjuster. The slack adjuster (Figure 3-9) serves two purposes— it changes the back-and-forth motion of the pushrod to rotary motion and makes minor adjustments to the brake shoes and linings.

(2) Operation. The slack adjuster is splined to one end of a shaft that goes through the backing plate of the wheel brake. The other end of the shaft contains a cam. When the air brake chamber pushrod moves the toe end of the slack adjuster, it causes the shaft to rotate. As the cam on the brake end of the shaft rotates, it causes the brake shoes and linings to move against the drum. Rotating the worn shaft on the slack adjuster makes a minor adjustment to the brakes. The wheel brake assemblies are much the same as those for hydraulic or air-over-hydraulic systems. The main difference is that the wheel cylinder is replaced with an operating cam.

Figure 3-9. Slack adjuster
PART B - TROUBLESHOOTING

3-3. **Introduction.** This lesson provides information required for diagnosing and correcting the unsatisfactory operation or the failure of an item of engineer construction equipment and its components is provided in this lesson. A job situation has been created that requires the use of a maintenance allocation chart (Appendix D, pages D-16) and a troubleshooting guide (Appendix D, pages D-17 and D-18).

3-4. **Requirement.** The equipment used throughout the job situation is a Harnischfeger Model MT-250 25-ton crane. Your requirement is to troubleshoot the problem and take the appropriate corrective action. Your duty assignment will be the same as in Lesson 2 (page 2-9), and an operator will assist you. Safety is a prime consideration. Ensure that the engine is shut off, all control and transmission levers are in the neutral position, the parking brake is set, and the wheels are chocked.

3-5. **Initial Situation.** You have been assigned to troubleshoot the brake system on a Harnischfeger Model MT-250 25-ton crane. The fault description on DA Form 5988-E (Figure 3-10, page 3-12) states that air pressure will not build to the normal pressure and air can be heard escaping around the air tank. A visual inspection reveals a ruptured air tank. The following paragraphs show what actions need to be taken:

a. **Interpret the inspection data.** Use steps 1 through 3 below to perform this task:

   Step 1. Based on the fault description information from DA Form 5988-E, use the maintenance allocation chart (Appendix D, page D-16) to determine what maintenance level has the responsibility for replacing the air tank.

   Step 2. If the operation is at the organizational level, use Appendix D, pages D-19 and D-20, to determine the figure and item numbers, the correct equipment nomenclature (NOUN), and the part or national stock number (NSN).

   Step 3. A quick look at Appendix D, page D-16, shows that replacement of an air-tank is an organizational maintenance responsibility. You should have located the air tank under its correct equipment NOUN of "reservoir, air." The air reservoir in Appendix D, pages D-19 and D-20, refers to reference number 52 and part number 27Z5. The maintenance supervisor has instructed you to remove and install the air reservoir; however, this lesson will not go into the steps required but will move to the next situation.

b. **Determine what caused the air reservoir to erupt.** When checking the troubleshooting guide (Appendix D, pages D-17 and D-18), you noted statements, concerning broken, leaking, or restricted tubing or hose lines. These were listed under all of the following malfunctions: brakes apply too slowly, brakes release too slowly, brakes do not apply, brakes do not release, air pressure drops quickly with engine stopped and brakes released, and air pressure drops quickly with engine stopped and brakes fully applied. Broken, leaking, or restricted tubing or hose lines are the cause of many malfunctions. You have been instructed by the maintenance supervisor to replace the hose assembly. Use the following steps to perform this task:
Figure 3-10. Sample DA Form 5988-E

Step 1. Check Appendix D, page D-16, to confirm that replacing the hose assembly is an organizational-level task.

Step 2. Determine the materials required to replace the hose assembly by using Appendix D, pages D-19 and D-20. Reference number 20 is the material needed to replace the hose assembly (part number 820P292D2, hose assembly, treadle service and supply, and two each). Steps for replacing the hose assembly will not be covered in this lesson.
c. Repair service brakes. Use the following steps to perform this task:

**Step 1.** Use Appendix D, page D-16, to determine the maintenance functions you are authorized to perform on the service brakes.

**Step 2.** As indicated in Appendix D, page D-16, service brake adjustment is authorized for organizational maintenance. Figure 3-11, page 3-14, shows the slack adjuster with its locking sleeve and (Figure 3-12, page 3-14) shows the adjusting screw installed on the front wheel brake chamber. Repair the service brakes as follows:

- Use the outriggers to raise the wheels off the ground.
- Push in the locking sleeve on the slack adjuster and turn the adjusting screw until the stroke required to apply the brakes is reduced to 1 inch.

**NOTE:** Use either an open-end or socket wrench to turn the adjusting screw. Ensure that the locking sleeve is held in, thereby disengaging the locking mechanism. Never use a wrench on the locking sleeve.

- Check the brake adjustment by making several brake applications. The air-chamber pushrod should move a total of 1 inch from the released position to the applied position.
- Ensure that the brake shoes are not dragging by releasing the brakes and spinning the wheel by hand.

**NOTE:** Use a feeler gauge to check the lining-to-drum clearance of the front brakes. If the clearance is more than 0.06 inch (1.5 mm), adjust the brakes manually as described below and schedule the vehicle for brake service.

- Jack or hoist the front wheels off the ground.
- Remove the dustcover from the adjusting slots above and below the brake chambers.
- The adjusting bolts have right-handed threads. Use an adjusting spoon to turn the steering wheel until a heavy drag develops, then back off the star wheel to a light drag on the drum. Reinstall the dustcovers in the adjusting slots.
Figure 3-11. Slack adjusters

Figure 3-12. Front wheel brake chamber
d. Perform a leakage test. Periodically, a leakage test is performed to determine whether a brake chamber is suitable for continued service. You have been assigned this task. Use the following steps to test for leakage (Figure 3-13):

Step 1. Have the operator make and hold a full brake application.

Step 2. Coat the nonpressure housing, the clamping ring, and the inlet ports and fittings with a soap solution. Ensure that there is no leakage at these points.

Step 3. Tighten the clamp bolt only enough to stop the leakage if leakage is detected around the clamping ring. Tightening the clamp bolt excessively could distort the diaphragm sealing flange.

Step 4. Disassemble and repair the brake chamber if leakage occurs at the nonpressure housing or if leakage cannot be stopped by tightening the clamp bolt.

![Brake chamber diagram](image)

**Figure 3-13. Brake chamber**

e. Replace the brake chamber. According to the maintenance allocation chart (Appendix D, page D-16), replacement of the brake chambers is a function of organizational-level maintenance.
To replace the front brake chamber, it must be removed before it can be disassembled and reassembled. Use steps 1 through 5 below to remove the brake chamber (Figure 3-14):

Step 1. Release all the air pressure.
Step 2. Remove the slack-adjuster cotter pin.
Step 3. Unscrew the air-line connector at the rear of the brake.
Step 4. Remove the mounting nuts and washers.
Step 5. Remove the front brake chamber.

Figure 3-14. Front brake chamber

(2) To disassemble and reassemble the front brake chamber, refer to Figure 3-15 and use the following steps listed for each procedure:
Disassemble. The following steps describe the method for removing the diaphragm and the boot. These items are the ones that cause leakage when the brake chamber is on the machine.

Step 1. Disconnect the air line or lines at the brake chamber.

Step 2. Remove the clamp ring and the nut bolt. While holding the pressure housing in place, spread the clamp ring and remove it.

Step 3. Hold the diaphragm against the nonpressure housing and remove the pressure housing.

Step 4. Remove the diaphragm carefully while holding the diaphragm plate against the wedge rod. This prevents the wedge assembly from coming out of engagement with the plungers.

**NOTE:** If the wedge assembly backs out of the plungers at anytime during the procedure, it will be necessary to remove the brake shoes to replace the wedge assembly.

Step 5. Continue to hold the diaphragm plate and inspect the boot. If the boot is torn or not attached to the nonpressure housing, strip the old boot from the housing.
Step 6. Extract the diaphragm plate carefully from the wedge assembly. The boot and the wedge guide will remain on the diaphragm-plate pushrod.

(b) Reassemble. The following steps describe the method for installing a new diaphragm and boot.

Step 1. Install a new boot on the diaphragm-plate pushrod and press the wedge guide all the way to the end of the pushrod.

Step 2. Clean the nonpressure housing with cement thinner or a similar solvent in the area where the boot is to be cemented.

Step 3. Apply cement around the tube end of the nonpressure housing. Position the diaphragm-plate pushrod in the tube. Carefully engage the wedge rod so that it does not pull out of the plungers.

Step 4. Press the boot into position for cementing while holding the diaphragm against the wedge assembly.

Step 5. Install a new diaphragm over the diaphragm plate and onto the nonpressure housing while pushing the diaphragm plate against the wedge assembly.

Step 6. Install the pressure housing over the diaphragm. Install the clamps ring over the nonpressure and pressure housing flanges. Secure the clamp ring with the clamp-ring bolt and nut.

Step 7. Reconnect the air line or lines to the brake chamber. Have the operator make and hold a full brake application and check the brake chamber for leakage. Check the brake performance by road testing the machine.
LESSON 3

PRACTICE EXERCISE

The following items will test your grasp of the material covered in this lesson. There is only one correct answer for each item. When you complete the exercise, check your answer with the answer key that follows. If you answer any item incorrectly, study again that part of the lesson which contains the portion involved.

1. Gasses, unlike liquids, are easily__________________.
   A. Compressed
   B. Transferred
   C. Exerted
   D. Transmitted

2. Driven by an engine, compressed air is forced into a reservoir by a/an___________.
   A. Diaphragm or air pump
   B. Air pump or governor
   C. Compressor or diaphragm
   D. Air pump or compressor

3. How many major components make up a typical air brake system?
   A. Five
   B. Six
   C. Seven
   D. Eight

4. Which component receives air and stores it for use in a braking system?
   A. Governor
   B. Reservoir
   C. Relay valve
   D. Brake chamber

5. Which valve controls brake operation by directing the flow of air from the reservoir to the brake chambers when the brakes are applied?
   A. Air brake
   B. Quick release
   C. Relay
   D. Compressor
6. Which test should be performed periodically to determine whether a brake chamber is suitable for continued service?

A. Road  
B. Operational  
C. Leakage  
D. Pressure

7. Which tool should be used to check the lining-to-drum clearance of the front brakes on a Harnischfeger Model MT 250 crane?

A. Ruler  
B. Micrometer  
C. Feeler gauge  
D. Tape measure

8. Which component limits the pressure produced by the compressor to a predetermined range?

A. Governor  
B. Brake chamber  
C. Slack adjuster  
D. Quick-release valve

9. If the brake chamber is defective, there are only two components that could cause the brake chamber to leak. One of these is the boot, the other is the

A. Diaphragm plate  
B. Diaphragm  
C. Pressure housing  
D. Clamp ring

10. If leaking occurs at the nonpressure housing or if leakage cannot be stopped by tightening the clamp bolt, the brake chamber should be

A. Replaced  
B. Welded  
C. Disassembled and repaired  
D. Disassembled and fabricated
LESSON 3

PRACTICE EXERCISE

ANSWER KEY AND FEEDBACK

<table>
<thead>
<tr>
<th>Item</th>
<th>Correct Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>A. Compressed</td>
</tr>
<tr>
<td></td>
<td>Unlike liquids, gasses are compressed easily. (page 3-1, para 3-1)</td>
</tr>
<tr>
<td>2.</td>
<td>D. Air pump or compressor</td>
</tr>
<tr>
<td></td>
<td>A pump or compressor driven ... (page 3-3, para 3-2)</td>
</tr>
<tr>
<td>3.</td>
<td>D. Eight</td>
</tr>
<tr>
<td></td>
<td>The compressed air brake system ... (page 3-2, para 3-2)</td>
</tr>
<tr>
<td>4.</td>
<td>B. Reservoir</td>
</tr>
<tr>
<td></td>
<td>The air reservoir ... (page 3-4, para 3-2a)</td>
</tr>
<tr>
<td>5.</td>
<td>A. Air brake</td>
</tr>
<tr>
<td></td>
<td>This component controls... (page 3-6, para 3-2c)</td>
</tr>
<tr>
<td>6.</td>
<td>C. Leakage</td>
</tr>
<tr>
<td></td>
<td>Periodically, a leakage test is ... (page 3-15, para 3-5d)</td>
</tr>
<tr>
<td>7.</td>
<td>C. Feeler gauge</td>
</tr>
<tr>
<td></td>
<td>NOTE: Use a feeler gauge ... (page 3-13, para 3-5c, step 2)</td>
</tr>
<tr>
<td>8.</td>
<td>A. Governor</td>
</tr>
<tr>
<td></td>
<td>This component limits ... (page 3-5, para 3-2b)</td>
</tr>
<tr>
<td>9.</td>
<td>B. Diaphragm</td>
</tr>
<tr>
<td></td>
<td>Disassemble. The following steps describe ... (page 3-17, para 3-5e [2] [a])</td>
</tr>
<tr>
<td>10.</td>
<td>C. Disassembled and repaired</td>
</tr>
<tr>
<td></td>
<td>Disassemble and repair ... (page 3-15, para 3-5d, step 4)</td>
</tr>
</tbody>
</table>
LESSON 4

AIR-OVER-HYDRAULIC BRAKE SYSTEMS

Critical Tasks: 091-62B-1005
091-62B-3054

OVERVIEW

LESSON DESCRIPTION:

In this lesson, you will learn about the principles of an air-over-hydraulic brake system and its major components. You will also learn how to troubleshoot, adjust, and repair this system on an MW24C scoop-type loader.

TERMINAL LEARNING OBJECTIVE:

ACTION: You will learn the principles of air-over-hydraulic brake systems.

CONDITION: You will be given the material contained in this lesson.

STANDARD: You will correctly answer practice exercise questions at the end of this lesson.

REFERENCES: The material contained in this lesson was derived from TMs 5-3805-262-10, 5-3805-262-20, 5-3805-262-24P, and 5-3805-262-34, 9-8000.

INTRODUCTION

Most passenger cars and light-duty trucks have a straight hydraulic brake system that uses only the energy that is applied to the brake's foot pedal. This type of brake does a good job on light-duty vehicles, but medium- and heavy-duty vehicles require a better braking system. The Army's 2 1/2-ton and some 5-ton tactical-design trucks have air-over-hydraulic brakes. Air-over-hydraulic brakes have hydraulics and compressed-air systems. The hydraulic systems of straight hydraulic brakes and air-over-hydraulic brakes are about the same. The compressed-air system supplies air pressure to boost the hydraulic pressure to the wheel cylinders above the amount supplied from the master cylinder.
4-1. Components. The air-over-hydraulic brake system (Figure 4-1) has all the components of a straight hydraulic system, plus those of the compressed-air brake system. Therefore, this lesson will review those components and will show how the two systems work together to form one system. The major difference in this system and an air brake system is the brake actuator (or power cluster). The actuator converts air pressure to hydraulic pressure for applying the brakes. In contrast, the brake actuators in the total air system convert air pressure to mechanical force for applying the brakes. Besides boosting the hydraulic pressure of the brakes on the truck or piece of engineer equipment, the compressed-air system can also be used to apply the brakes of a trailer and operate accessories such as the wiper motor and horn. The major components of this system and their functions within the system are discussed below:

![Figure 4-1. Air-over-hydraulic brake system](image)

a. Air compressor. The air compressor is mounted on the top or side of the engine and compresses the air that is used to actuate the hydraulic master cylinders for the brakes. The compressor is driven by a belt connected to the engine and runs only when the engine runs. Air compressed by the compressor passes through the governor that is connected between the air reservoir and the compressor. The governor controls the pressure level in the system by
starting or stopping compression of air at specified pressures. If the governor does not work correctly, a relief valve connected to the air reservoir opens at 150 psi to prevent damage to the air system.

b. Air reservoir. Compressed air from the compressor flows to the air reservoir for storage until the compressed air is needed by components in the air system. There is a check valve at the air-reservoir inlet so that the compressed air cannot flow back to the compressor.

c. Brake valves. Brake valves, sometimes called treadle valves, control the flow of air to the brake actuators. Each brake valve has a rubber spring. By pushing the brake pedal, pressure is put on the rubber spring. The rubber spring pushes back against your foot so that more pressure is necessary to push the brake pedal further. The system lets you control the pressure in the brake system with more accuracy. Figure 4-2, page 4-4, shows the components of the brake pedal and the rubber spring. When the pedal is pushed, force is applied through the rubber spring to the piston and the piston moves down. The stem of the piston makes contact with the valve for inlet and exhaust. When the stem, which is the exhaust seat, makes contact with the valve, the exhaust port from the upper chamber is closed. As the piston continues to move down, the stem pushes the valve off the inlet seat, opening the inlet port to the upper chamber. Air supply from the air reservoir flows through the inlet seat and into the upper chamber. From the upper chamber, the air supply flows to the brake actuators and to the other components connected to the upper chamber.

d. Brake actuators. The brake system on an MW24C scoop-type loader has two brake actuators, one each for the front and rear wheels. Figure 4-3, page 4-5, shows a disassembled brake actuator. The brake valve controls operation of the brake actuator. Either of the two brake valves control the flow of air to both brake actuators. Each brake actuator has an air chamber and a hydraulic master cylinder. Air pressure from the brake valves flows to the air chamber of each brake actuator. The air pressure pushes the diaphragm and the pushrod into the air chamber. The pushrod pushes the piston in the master cylinder, which increases the hydraulic pressure in the brake lines and applies the brakes.

e. Master cylinder. The master cylinder used with air-over-hydraulic brakes is like the one described in Lesson 2. In straight hydraulic brake systems, the master cylinder receives the initial mechanical force from the pedal linkage, changes it to hydraulic pressure, and sends the brake fluid under pressure directly to the wheel cylinders. In air-over-hydraulic brakes, the master cylinder sends brake fluid under pressure to an air-over-hydraulic cylinder before it goes to the wheel cylinders. On all military-designed vehicles, the master cylinder has a vent fitting at the top of the reservoir for connecting a vent line to the vent system of the vehicle. This prevents water from entering the master cylinder through the vent during fording operations. The special drilled bolt and fitting installed in the filler cap of the master cylinder serves this purpose.

f. Air-over-hydraulic cylinder. This cylinder is put into operation by the hydraulic pressure from the master cylinder. It uses compressed air to boost the hydraulic pressure from the master cylinder. The Army uses more than one model of air-over-hydraulic cylinders; all models contain the same major units and operate on the same principles. The units are
made up of three major units in one assembly—the control unit, the power cylinder, and the slave cylinder. The units of the M809-series vehicles consist of an air valve, air cylinder, a hydraulic cylinder, and a piston.

Control unit. The control unit contains a control-valve (relay) piston, which is hydraulically operated by brake fluid from the master cylinder, and a diaphragm or compressor assembly, which is operated by pressure differences between brake fluid and air and spring pressure. A return spring holds the hydraulic-relay piston and the diaphragm assembly in the released positions when there is no hydraulic pressure. Two air poppets, assembled on one stem control the air pressure flowing in and out of the power cylinder. The poppets are normally held in the released position by the poppet return spring.
4-2. **Introduction.** This learning event provides information useful in diagnosing and correcting unsatisfactory operation or failure of an item of engineer construction equipment and its components. Job situations have been created requiring the use of DA Form 5988-E (Figure 4-4, page 4-6), the troubleshooting guide (Appendix D, pages D-21 through D-25), and the appropriate maintenance allocation chart (Appendix D, pages D-26 and D-27).
Figure 4-4. Sample DA Form 5988-E

4-3. Requirement. The piece of equipment used throughout the following situations will be a loader, scoop-type, diesel engine driven (DED), 4 by 4, articulated frame steer, 2 1/2 cubic yard, (J. I. Case Model MW24C). Your duty position and unit of assignment will be the same as in Lessons 2 and 3. An operator will be present to assist you. Safety will always be a prime
consideration. Ensure that the engine is shut off, the control and transmission levers are in the neutral position, the parking brake is set, and the wheels are chocked.

a. In this situation, use the maintenance allocation chart (Appendix D, pages D-26 and D-27) to identify the brake group numbers in column one. Determine who is authorized to replace the hydraulic brake lines and the brake-treadle valve.

Problem: Who can adjust the wheel disk brakes?

Solution: After examining the maintenance allocation chart, you should have determined that organizational maintenance has the responsibility to replace the brake lines and the brake-treadle valve.

b. In this situation, you have been assigned to troubleshoot a an MW24C scoop-type loader. DA Form 5988-E (Figure 4-4) states that the "wheel brakes do not work." During your personal inspection you determine that—

- There is sufficient air pressure present.
- There is no indication of a break in the air lines.
- The hydraulic fluid is low in the power cluster.
- The compressor belt is tight.

Problem: Based on this information, determine the probable cause of the malfunction and the appropriate corrective action. Use the troubleshooting guide shown in Appendix D, pages D-21 through D-25.

Solution: The probable cause is insufficient hydraulic fluid in the actuator; and the corrective action is to add fluid, bleed the brake system, and road test the loader.

NOTE: To bleed air from the brake system and fill it with hydraulic fluid, refer to Appendix D, pages D-21 through D-25, D-28, and D-29.

c. This situation involves filling the actuator and road testing the scoop-type loader. While road testing the scoop loader, you find the service brakes will not stop the machine.

Problem: Based on the information above, determine the probable cause of the malfunction and the appropriate corrective action. Use the troubleshooting guide in Appendix D, pages D-21 through D-25.

Solution: Since there are no indications of air or fluid leaks, the logical assumption is that the disk brakes need to be inspected. After looking at the maintenance allocation chart, you determined that the inspection is done by organizational maintenance. (Refer to Appendix D, page D-32, for inspection steps.) You have determined through the inspection of the disk brakes that the lining measurements were less than 2.54 millimeters.
A quick look at the maintenance allocation chart (Appendix D, pages D-26 and D-27) shows that replacement of the brake linings is an organizational maintenance responsibility. You should have located the linings under the correct nomenclature of linings, friction by using the parts manual extract (Appendix D, pages D-37 through D-42). The linings are item number 3 and its part number is 9640184, which is part of a kit 9680436. Looking at the extract of the cross-reference indexes (Appendix D, pages D-37 through D-42), the NSN for the kit is 2530-01-180-0799. (For information on removing, cleaning, inspecting, and installing the brake linings, refer to Appendix D, pages D-33 through D-36.)

d. This situation involves the use of the parking brake. The parking brake holds the loader in position while it is parked and also acts as an emergency brake. The loader cannot be moved until at least 65 psi of pressure has been built up in the air system. The air pressure acting on the brake actuator overcomes the spring pressure and releases the parking brake. The brake is mounted on the transmission, and a valve mounted on the instrument panel operates the brake actuation. When the valve lever is pulled out, the air is exhausted, allowing the springs to set the brake. You have been given a DA Form 5988-E (Figure 4-4, page 4-6) stating that "the parking brake will not hold the loader while parked."

Problem: Determine which level of maintenance has the responsibility for adjustment, replacement, and repair of the parking brake.

Solution: By looking at the maintenance allocation chart (Appendix D, pages D-26 and D-27), you find that organizational maintenance has the responsibility for adjusting, replacing, and repairing the parking brake. (Use the steps provided in Appendix D, page D-31, to adjust the parking brake.)

e. While adjusting the scoop loader's parking brake, you find that the nut on the actuator rod is stripped.

Problem: Use the maintenance allocation chart (Appendix D, pages D-26 and D-27) to determine who is responsible for the repair.

Solution: If you looked at the maintenance allocation chart for the one responsible for the repair, situation d clearly stated that organizational maintenance is responsible for adjusting, replacing, and repairing the parking brake linkage.

**NOTE:** Use the steps in Appendix D, page D-31, to replace the nut.

f. In this situation, you will be working with the brake treadle valve.

Problem: What level of maintenance is authorized to replace the brake treadle valve?

Solution: Removal. Refer to Appendix D, pages D-43 and D-44, for the removal and installation of a brake treadle valve.
The following items will test your grasp of the material covered in this lesson. There is only one correct answer to each item. When you complete the exercise, check your answer with the answer key that follows. If you answer any item incorrectly, study again that part of the lesson which contains the portion involved.

1. What is the essential difference between the hydraulic brake system and the air-over-hydraulic brake system?
   A. Master cylinder
   B. Power cluster
   C. Air supply
   D. Safety valve

2. What is the probable cause for inoperative wheel brakes?
   A. Insufficient air pressure
   B. Loose compressor belt
   C. Insufficient hydraulic fluid in the power-cluster reservoir
   D. All the above

3. What controls the flow of air to the brake actuators?
   A. Governor
   B. Air compressor
   C. Treadle valve
   D. All the above

4. The thickness for each lining must be more than ________ millimeter s).
   A. 12.7
   B. 0.1
   C. 2.54
   D. None of the above

5. Use a __________ to push the brake-caliper pistons into the brake-caliper body.
   A. Screwdriver
   B. Pry bar
   C. Brake adjusting tool
   D. Box-end wrench
6. Whenever a component or line in the brake system is disconnected for servicing, what must be done?
   A. Chock the vehicle
   B. Bleed air from the system
   C. Run the engine at 500 revolutions per minute (rpm)
   D. None of the above

7. The loader cannot be operated until there is an air pressure reading of approximately psi.
   A. 65
   B. 75
   C. 85
   D. 95

8. The parking brake holds the loader in position while it is parked. It also acts as a/an
   A. Pressure-release valve
   B. Brake chamber
   C. Emergency brake
   D. Brake treadle
### LESSON 4

**PRACTICE EXERCISE**

**ANSWER KEY AND FEEDBACK**

<table>
<thead>
<tr>
<th>Item</th>
<th>Correct Answer and Feedback</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>B. Power cluster&lt;br&gt;The major difference ... (page 4-2, para 4-1)</td>
</tr>
<tr>
<td>2.</td>
<td>D. All the above&lt;br&gt;During your personal inspection ... (page 4-7, para 4-3b)</td>
</tr>
<tr>
<td>3.</td>
<td>C. Treadle valve&lt;br&gt;Brake valves, sometimes called ... (page 4-3, para 4-1c)</td>
</tr>
<tr>
<td>4.</td>
<td>B. 0.1&lt;br&gt;Thickness of each lining ... (page D-32, para 7-2a[1] [b])</td>
</tr>
<tr>
<td>5.</td>
<td>B. Pry bar&lt;br&gt;Using pry bar ... (page D-34 para 7-2a[21][d])</td>
</tr>
<tr>
<td>6.</td>
<td>B. Bleed air from the system&lt;br&gt;Whenever a component line ... (page D-28, para 7-2c, Warning)</td>
</tr>
<tr>
<td>7.</td>
<td>A. 65&lt;br&gt;The loader cannot be moved ... (page 4-8, para 4-3d)</td>
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<tr>
<td>8.</td>
<td>C. Emergency brake&lt;br&gt;The parking brake holds ... (page 4-8, para 4-3d)</td>
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LESSON 5

D7G BRAKE SYSTEM

Critical Tasks: 091-62B-1005
091-62B-3054

OVERVIEW

LESSON DESCRIPTION:

In this lesson, you will learn about the principles of the brake system on a D7G tractor. You will learn how to troubleshoot, adjust, and repair the winch brake system.

TERMINAL LEARNING OBJECTIVE:

ACTION: You will identify the steps used to troubleshoot, repair, and adjust the brake system on a D7G tractor.

CONDITION: You will be given the material contained in this lesson.

STANDARD: You will correctly answer practice exercise questions at the end of the lesson.

REFERENCES: The material contained in this lesson was derived from TMs 5-2410-237-10 and 5-2410-237-20.

INTRODUCTION

Most brake systems have internal nonrotating brake bands. They expand to a rotating brake drum that is used to slow down or stop the moving vehicle. The slow-down or stopping power in most brake systems is assisted by air- or hydraulic-type systems. The external-contracting brake for the D7G tractor has the same objective—to slow or stop the tractor. In addition, it must steer the equipment because of its independent brake system.

PART A - OPERATION

5-1. General. The tractor has two, band-type brakes (one on each steering-clutch drum) which are used to slow or stop the tractor and assist with steering the tractor. When the steering levers are pulled completely out, or the brake pedals are depressed, the bands tighten around the steering-clutch drum.

a. Steering-clutch drum. There is one clutch which controls the steering of the tractor for each track. The steering-clutch lever in the operator's station controls the hydraulically
operated clutch. When turning left, the left clutch is released. This causes the left track to stop moving, and the track functions as a pivot for the tractor to turn on. The same thing happens when turning right.

b. Control valve. The control valve is connected mechanically to the steering control levers. The valve directs the flow of oil pressure in response to the movement of the control levers.

5-2. Brake Mechanisms. Brake mechanisms may be of different designs, but they all require a rotating unit and a nonrotating unit. The rotating unit consists of a drum connected to a shaft. The nonrotating unit consists of brake shoes and the linkage -necessary to apply the shoes to the drum. Depending on how the nonrotating braking surface is forced against the rotating braking surface, the brakes are either an external-contracting or internal-expanding type.

5-3. External-Contracting Brake. When the brake shoes of the brake bands are applied against the outside of the rotating brake drum, the brake is known as an external-contracting brake. The nonrotating braking surface must be forced inward around the drum to produce the friction necessary for braking. This type of external-contracting band is found on the D7G brake system (Figure 5-1). The brake band is tightened around the drum by moving a lever. If a proper cover is not provided, the external-contracting brake is exposed to dirt, water, and other foreign matter. This exposure rapidly wears the lining and drum, destroying their frictional properties.

PART B -TROUBLESHOOTING

5-4. Introduction. Information required for diagnosing and correcting the unsatisfactory operation or failure of an item of engineer construction equipment and its components is provided in this lesson. Job situations have been created requiring the use of a DA. Form 5988-E (Figure 5-2, page 5-4), a maintenance allocation chart (Appendix D, page D-47), and a troubleshooting guide (Appendix D, pages D-45 and D-46). Equipment used throughout these situations will be a tractor, full-track, model D7G.

5-5. Requirement. Your requirement for each situation is to troubleshoot the problem and take the appropriate corrective action. Your duty assignment will be the same as in the previous lessons. An operator will be available to assist you. Safety is a prime consideration. Ensure that the engine is shut off and the control and transmission levers are in the neutral position.

5-6. Initial Situation. You have been assigned to troubleshoot the steering system on the D7G tractor.
a. Review DA Form 5988-E (Figure 5-2, page 5-4). Figure 5-2 indicates that the brakes failed to stop the tractor with either brake pedal and the brakes failed to turn in either direction.

Problem: After road testing the tractor for the discrepancies noted, which of the following sources should you use to narrow down the possible causes and their remedies?

a. Maintenance supervisor

b. Parts manual

c. Troubleshooting guide

d. Maintenance allocation chart

Solution: The correct choice is c. The troubleshooting guide (Appendix D, pages D-45 and D-46) indicates that the steering or the brake linkage may be out of adjustment.
Review of the maintenance allocation chart (Appendix D, page D-47) indicates that organizational maintenance is the authorized level to adjust the steering and brake linkages.

b. Inspect linkages and make corrections. Inspection of the steering and brake linkage indicates that the steering-linkage measurement is correct; however, the brake-linkage measurement is not. Use the following steps to make adjustments on the brake

Figure 5-2. Sample DA Form 5988-E

EN5258 5-4
linkage (Figure 5-3). You have a new gasket and cotter pins on hand, and the floor plates have been removed. The steps listed below are for the right side of the tractor; repeat them for the left side. Refer to Figure 5-3 while making the adjustments.

**Figure 5-3. Brake-shoe cover plate and brake linkage**

Step 1. Use a wrench to remove the three cap screws (1) and the washers (2) from the cover plate (3).

Step 2. Remove the cover plate (3) with gasket (6) from the top of the final drive case (4) to gain access to the brake-band adjusting nut (5). Discard the old gasket.

Step 3. Use a wrench to turn the brake band adjusting nut (5) clockwise until the band is tight, and then loosen the nut 1 1/2 turns (9 clicks) counterclockwise.

Step 4. Remove the rod (10) by removing the cotter pins (7) and the pins (8 and 9). Discard the cotter pins.

Step 5. Use two wrenches to loosen the nut (11) at both ends of the rod (10).

Step 6. Turn the rod (10) until the distance between the center line of the pins (8 and 9) is 19.25 inches, plus or minus 0.02 inch.
Step 7. Use a wrench and a torque wrench to tighten the nut (11) to a torque of 75 foot-pounds.

Step 8. Install the rod (10) and secure it with pins (8 and 9) and new cotter pins (7).

Step 9. Use two wrenches to loosen the nut (12) on the rod (13).

Step 10. Turn the rod (13) until the distance between the centerlines of the pins (14 and 15) is 12.88 inches.

Step 11. Use a wrench and a torque wrench to tighten the nut (12) to a torque of 75 foot-pounds.

Step 12. Use two wrenches to loosen the nut (16) on the rod (17).

Step 13. Turn the rod end to adjust the length of the rod (17) so that the distance between the front of the right brake pedal (18) and the seat kick plate is 18.53 plus or minus 0.12 inch.

Step 14. Use a wrench and a torque wrench to tighten the nut (16) to a torque of 75 foot-pounds.

Step 15. Install the gasket (6) and the cover plate (3). Use a wrench to install three washers (2) and cap screws (1).

Step 16. Repeat steps 1 through 13 for the left side.

Step 17. Reinstall floor plates.

Step 18. Test drive the equipment for proper operation and return to service.
LESSON 5

PRACTICE EXERCISE

The following items will test your grasp of the material covered in this lesson. There is only one correct answer for each item. When you have completed the exercise, check your answer with the answer key that follows. If you answer any item incorrectly, study again that part of the lesson which contains the portion involved.

1. Which of the following units are required by brake mechanisms?
   A. Expanding and nonrotating
   B. Rotating and nonrotating
   C. Centrifugal and mechanical
   D. Hydraulic and centrifugal

2. Which of the following type brake is used by a D7G tractor?
   A. External-contracting
   B. Internal-expanding
   C. Internal-contracting
   D. External-expanding

3. What assists the brakes on a D7G?
   A. Air
   B. Hydraulics
   C. Both A and B
   D. None of the above

4. Which of the following is the correct distance between the front of the right brake pedal and the kick plate?
   A. 12.88 inches, plus or minus 0.12 inch
   B. 18.53 inches, plus or minus 0.12 inch
   C. 19.25 inches plus or minus 0.02 inch
   D. 75 inches, plus or minus 0.1 inch

5. Refer to Appendix D, page D-47. What maintenance level is authorized to replace the steering brakes on the D7G tractor?
   A. Operator
   B. Maintenance supervisor
   C. Direct support
   D. Organizational support
### LESSON 5

#### PRACTICE EXERCISE

#### ANSWER KEY AND FEEDBACK

<table>
<thead>
<tr>
<th>Item</th>
<th>Correct Answer</th>
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| 1.   | B. Rotating and nonrotating  
Brake mechanisms may be of different.  ...(page 5-2, para 5-2) |
| 2.   | A. External-contracting  
When the brake shoes of the ...  (page 5-2, para 5-3) |
| 3.   | C. Both A and B  
The slow down or stopping power ...  (page 5-1, Introduction) |
| 4.   | B. 18.53 inches, plus or minus 0.12 inch  
Turn the rod end to adjust ...  (page 5-6, para 5-5b, step 13) |
| 5.   | C. Direct support  
Appendix D (page D-47) |